July 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-269

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Inexpensive Chest for Conducting Frost-Heaving Experiments

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Laboratory equipment for conducting frost-heaving experiments with soil is expensive. A freezing chest constructed of plywood and styrofoam is described which can be built for approximately $60 (1974 costs). Freezing tests are conducted in 3- by 1.3-inch polyvinylchloride cylinders filled with soil.

Keyword: Frost heaving.

Frost heaving is a major cause of mortality of tree seedlings in many parts of the world. Studies by Larson (1961) and Heidmann (1974), as well as field observations, indicate that frost heaving may be the primary cause of first-year ponderosa pine mortality in Arizona. In spite of this fact, frost heaving has not been studied in detail by foresters or other workers in allied agricultural fields. A great deal of basic research needs to be done both in the laboratory and in the field. Unfortunately, laboratory equipment for conducting heaving experiments is quite expensive.

Numerous authors (Haley 1953; Higashi 1958; Jumikis 1956; Kaplar 1971; Taber 1929, 1930) have described different types of apparatus for conducting laboratory frost-heaving experiments. Most of this equipment is elaborate and expensive. In addition, most of the experiments conducted with these chests utilize cylinders of soil as large as 4 by 10 inches, which means few samples can be studied at one time. I recently concluded a comprehensive study of frost heaving in Arizona in which several experiments were conducted in a simple plywood chest. The frost-heaving characteristics of six soils, as well as methods of controlling heaving, were studied in small cylinders made of polyvinylchloride (PVC) plastic pipe.

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Construction of The Chest

The freezing chest, like most others described in the literature, is constructed to simulate an open system. A supply of water which does not freeze is continually available at the bottom of the soil sample, while the freezing occurs from the surface downward. The chest is open on the top and lined on the sides and bottom with styrofoam insulation. Soil cylinders are set in a pan of water in the chest; the water is kept from freezing by a heating tape. The whole apparatus is placed in a chest-type freezer which has been modified by replacing the original thermostat with one calling for warmer temperatures (up to 32° F).

The freezing chest is built of plywood 3/4-inch thick (fig. 1). The inside dimensions are 30 inches long, 18 inches wide, and 10 inches deep. The inside of the chest is lined with a white styrofoam sheet 2 inches thick. A heating tape is countersunk in the styrofoam on the bottom of the chest about 3 inches from the edges of the chest (fig. 1). The tape has a thermostat which is set to come on when the temperature drops

Figure 1.—Freezing chest used in frost-heaving experiments. The wire (top right) leads to a heating tape countersunk in the bottom piece of styrofoam, which is covered with a 1-inch piece of styrofoam with a lattice of holes to allow more heat to reach the water in the pan which rests on the styrofoam.

Figure 2.—Sheet metal pan which is placed in freezing chest. Pan is lined on the bottom with 1 inch of coarse sand. Ledges at each end of the pan hold a 2-inch styrofoam block containing soil cylinders.

Figure 3.—Sheet metal pan with styrofoam block which holds cylinders containing soil. A total of 72 cylinders can be studied at one time.

Figure 4.—Freezing box assembled. After soil cylinders are placed in the block, the whole apparatus is placed in a chest-type deep freeze unit.

below 38° F. A 1-inch-thick piece of styrofoam with a lattice of holes, 1-15/16 inches in diameter, 5 inches apart, is placed on top of the bottom piece of styrofoam which contains the heating tape, to allow more heat to flow to the water in the pan.

A pan 26 inches long, 14 inches wide, and 4 inches deep was constructed of sheet metal to hold the soil samples (fig. 2). On the inside of the pan at each end there is a 1/2-inch-wide ledge the width of the pan, 2 inches from the top of the pan. The bottom of the pan is lined with number 16 (coarse) sand to a depth of 1 inch. The sand is covered with approximately 1/2 inch of water (fig. 2). A piece of styrofoam 2 inches thick, 26 inches long, and 14 inches wide is set into the pan and rests on the ledges at the ends so that the top of the styrofoam is flush with the top of the pan. The styrofoam block contains 72 holes 1.3 inches in diameter on 2-inch centers (fig. 3). The holes are made with a piece of PVC plastic pipe which has been sharpened on the inside edge to make a punch.

The pan is placed in the freezing chest (fig. 4) and the chest is placed in a freezer.

Table 1 lists the materials needed to construct the box, and the approximate 1974 costs.

Table 1.--List of materials needed for constructing frost-heaving chest

Item	Amount required	Approx. cost
Plywood, 3/4 in (4 ft x 8 ft)	One-half sheet (4 ft x 4 ft)	$ 6.67
Styrofoam (2 in x 12 in x 30 in)	7 pieces	14.00
White glue (for styrofoam)	1 pt	2.00
Heating tape (9 ft)	One	5.50
Pan, sheet metal	One	25.30
PVC plastic pipe (1-3/16 in, i.d.)	20 ft	4.00
Sand (No. 16)	One sack	2.55
Total		60.02

Conducting the Freezing Tests

The freezing tests are conducted in small cylinders made of PVC pipe of the same diameter as the punch used for making the holes in the styrofoam. The cylinders are 3 inches long with an inside diameter of 1-3/16 inches. The cylinders are filled with oven-dried soil from which all of the material over 2 mm in size has been screened. One end of the cylinder is covered with several layers of cheesecloth held in place by a rubberband to prevent the soil from coming out the bottom. The cloth and rubberband are coated with rubber cement to make them adhere to the cylinders (fig. 5). The inside of each cylinder is coated with silicone applied as an aerosol spray.

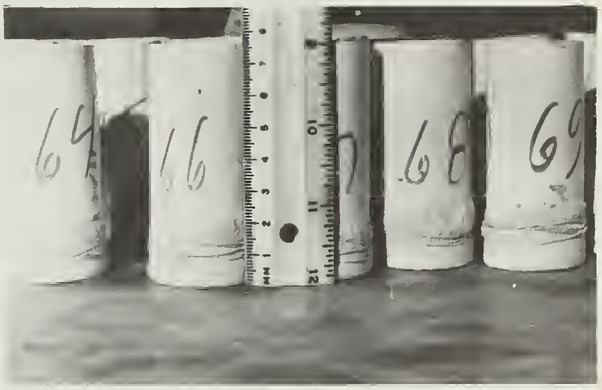

Figure 5.—Cylinders made of PVC plastic pipe are filled with soil and placed in sheet metal pan containing water. The bottom of each cylinder is covered with a piece of cheesecloth held in place by a rubberband and rubber cement.

Heaving is closely related to bulk density, or how much soil is packed into the cylinders. It is therefore necessary to determine the bulk densities desired for each soil to be tested. Calculate the volume of the cylinder to determine the amount of oven-dry soil needed, since the bulk density = mass/volume. The weight of soil needed per cylinder equals the bulk density times the volume, which is 3.4 inches^3.

At lower bulk densities, the soil may be packed into the cylinders dry. At higher bulk densities, it may be necessary to moisten the soil. The soil is packed by adding a small increment at a time to the cylinders and then hand-packing it with a hardwood dowel slightly smaller in diameter than the cylinder. When no more dry soil can be added to the cylinders, they are placed in a pan of water to saturate. After saturation, the packing is finished by adding the remaining dry soil to the cylinders. All soil samples are saturated before freezing tests are begun.

The cylinders with saturated soil are removed from the water and allowed to drain for a few seconds on paper towels to remove excess moisture, after which they are weighed to the nearest 0.1 g.

The weighed cylinders are inserted in the styrofoam block. The cylinders have to be inserted through the bottom of the block due to the cheesecloth and rubberband. The surface of

each cylinder is positioned so that it is flush with the styrofoam. After the block is loaded with cylinders, it is placed in the sheet metal pan. With this arrangement, just the surface of each cylinder is exposed to the ambient temperature in the freezer. The bottom of each cylinder rests on the coarse sand in the pan in approximately 1/2 inch of water.

During the first two or three trials, the cylinders fit snugly in the holes in the block. In subsequent trials, the holes become slightly enlarged and some of the cylinders slide out of the holes when attempting to place the block in the pan. This problem is solved by wrapping a piece of paper around the cylinder before inserting it into the hole.

After freezing begins, and the soil has heaved a short distance out of the top of the cylinder, it tends to dry out and crumble because the vapor pressure gradient is from the soil to the freezer, where the humidity runs between 80 and 90 percent. To prevent drying of the frozen soil, the soil surfaces are given a fine mist spray of water at least once a day.

On completion of the experiments, the amount that each soil has heaved out of the tops of the cylinders is measured to the nearest millimeter. When the cylinders are removed from the block, some of the soil cores may have also pushed out of the bottom (fig. 6). A method of holding the cylinder in place during freezing could be devised. Otherwise, the amount of heaving on the bottom is added to the amount of heaving on top to get a total heaving figure.

Figure 6.—Soil cylinders at the conclusion of a 10-day freezing experiment. Note that the soil column has heaved out of the bottom of the cylinders also, especially those on the right.

During all freezing experiments, the air temperature 1 inch above the surface of the block is monitored with a copper-constantan thermocouple. The water temperature is also monitored with a thermocouple and a mercury thermometer. In addition, an indoor-outdoor thermometer is placed in the freezer so that temperature can be determined roughly at a glance.

The ambient temperature 1 inch above the soil surfaces is maintained at approximately 27° F, while the water temperature is kept at about 36° F.

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